August 8, 2003

LICENSEE: STP Nuclear Operating Company

FACILITY: South Texas Project, Unit 1

SUBJECT: SUMMARY OF THE STAFF OBSERVATION/AUDIT/ASSESSMENT OF VISIT TO FRAMATOME, INC., IN LYNCHBURG, VA, STP NUCLEAR OPERATING COMPANY'S ASME SECTION III CLASS 1 DESIGN CALCULATIONS IN SUPPORT OF THE SOUTH TEXAS PROJECT, UNIT 1, HALF-NOZZLE REPAIR/REPLACEMENT ACTIVITIES (TAC NO: MB8435)

On June 18, 2003, the U. S. Nuclear Regulatory Commission (NRC) staff visited the Framatome, Inc., facility in Lynchburg, Virginia, for the purpose of observing, auditing, and assessing the American Society of Mechanical Engineers (ASME) Section III thermal and mechanical stress and fatigue design calculations. The design calculations are associated with "half-nozzle" repair/replacement activities on the reactor pressure vessel bottom-mounted instrumentation leaking penetrations at South Texas Project, Unit 1. These design calculations form part of the analytical support provided by Framatome, Inc., and Dominion Engineering, Inc., as consultants to STP Nuclear Operating Company (STPNOC). This audit was performed within the scope of the staff review, as part of the overall staff assessment of the repair/replacement activities. Enclosure 1 is a list of attendees. Enclosure 2 is the NRC staff's assessment. Enclosure 3 is STPNOC's July 2, 2003, calculation summary. Enclosure 4 is STPNOC's July 23, 2003, revised calculations summary.

Based on its observations, the staff noted that the calculations were performed in accordance with current industry practice and conform with the ASME Section III Class 1 design and fatigue requirements. However, the staff also identified two minor concerns that were conveyed to the STPNOC staff who were assisting the NRC staff's audit/observation visit to Framatome facility.

By letters dated July 2, 2003, and July 23, 2003, STPNOC respectively provided original and revised summaries of the Framatome and Dominion analyses, and also included responses to the staff concerns. The staff has reviewed these summaries and the responses to the concerns, and considers the concerns satisfactorily addressed (Enclosure 2).

/RA/

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Division of Licensing Project Management
Office of Nuclear Reactor Regulation

Docket No. 50-498

cc w/Enclosures: see next page

Enclosure 1. List of Attendees
Enclosure 2. The NRC Staff Assessment
Enclosure 3. STPNOC July 2, 2003, Calculations Summary (ADAMS Accession No.: ML031900204)
Enclosure 4. STPNOC July 23, 2003, Calculations Summary (ADAMS Accession No.: ML032060397)

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DATE	8/08/2003	8/08/2003	8/08/2003

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NRC OBSERVATIONS OF STP NUCLEAR OPERATING COMPANY CONTRACTOR'S

ANALYSES OF DESIGN AND REPAIR CALCULATIONS FOR

SOUTH TEXAS PROJECT BOTTOM-MOUNTED INSTRUMENTATION LEAKAGE

JUNE 18, 2003, MEETING ATTENDEE'S LIST

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STAFF ASSESSMENT OF ASME SECTION III CLASS 1 DESIGN CALCULATIONS

IN SUPPORT OF THE SOUTH TEXAS PROJECT, UNIT 1

HALF-NOZZLE REPAIR/REPLACEMENT ACTIVITIES

MECHANICAL AND CIVIL ENGINEERING BRANCH

DIVISION OF ENGINEERING

BACKGROUND

On June 18, 2003, staff from the U. S. Nuclear Regulatory Commission's (NRC's) Branch of Mechanical and Civil Engineering (EMEB) visited the Framatome, Inc., facility in Lynchburg, VA, for the purpose of observing/auditing the American Society of Mechanical Engineers (ASME) Section III thermal and mechanical stress and fatigue design calculations associated with "half-nozzle" repair/replacement activities on the reactor pressure vessel (RPV) bottom head instrument leaking penetrations at South Texas Project (STP), Unit 1. These design calculations form part of the analytical support provided by Framatome, Inc., as consultant to STP. The audit was performed within the scope of review of the EMEB, as part of the overall staff evaluation of these activities.

EVALUATION

The analyses were performed with the computer program ANSYS, which has extensive capabilities for performing highly complex three-dimensional heat transfer analysis and elastic and elastic-plastic thermal stress analysis of solids, both static and dynamic. ANSYS is a finite element method (FEM) type commercially available program, widely used in the nuclear and non-nuclear industries, and recognized by the NRC staff as an acceptable program for performing these types of analyses. A significant feature of ANSYS is its graphic pre-processing and post-processing capabilities, which permit verifying input data and resulting output data of very large finite element models for consistency and reasonableness.

The calculations were sampled for conformance with:

1) Current licensing basis design mechanical and thermal transients.

2) Proper material properties.

3) Currently accepted stress analysis methodology.

4) Conformance with ASME Section III Class 1 design stress and fatigue criteria.

Two types of analyses were performed: transient heat transfer analyses, to generate thermal time histories for input into the mechanical stress analysis, followed by the calculation of the stresses. The results of the stress analyses for the various transient loading conditions were input into ASME Section III Class 1 fatigue analyses, from which the highest fatigue usage factors were calculated. The heat transfer analyses were performed using the ANSYS capabilities for such analyses. The input to these analyses consisted of thermal transients, such as heat up and cool down transients, operational, and test transients. Both analyses, using the same finite element geometric model, were done interactively, i. e., the stresses at various locations were calculated at selected time intervals to capture the highest stresses for a given thermal transient. The stress analyses also included the corresponding mechanical loads for each thermal transient. Stress analyses were also performed for emergency and faulted conditions. The extensive list of thermal and mechanical design transients used in these analyses corresponded to those in the original design specification for the plant, and accepted under the current licensing basis.

The penetration configuration and the types of analysis performed at various locations are shown in Figure 1. The following calculation packages were sampled:

- 32-5028841, STP, Unit 1, Bottom Mounted Instrumentation (BMI) Connection Analysis and Qualification

- 32-5028839, STP, Unit 1, BMI Nozzle to Guide Tube Connection Analysis and Qualification (Socket Weld)

- C-3714-00-1, Rev. 1, BMI Nozzle Stress Analysis (Residual Stress Analysis)

The first two analyses were performed by Framatome, Inc. The last analysis was performed by Dominion Engineering, Inc., another subcontractor to STP.

ASSESSMENT

- 32-5028841, STP, Unit 1, Bottom Mounted Instrumentation (BMI) Connection Analysis and Qualification

In Calculation 32-5028841, Framatome analyzed the bottom mounted penetration region encompassing Penetration No. 58. Although no leaks were found at this location, this penetration has the steepest inclination with respect to the normal to the RPV bottom head wall, and the analysis of this penetration, therefore, represents a bounding analysis for all penetrations. The region, with the half-nozzle repair option, was represented by a highly refined finite element model, in the order of 80,000 three-dimensional elements and 120,000 nodes. The model included a segment of the reactor vessel wall and cladding, the existing internal surface J-weld, the Alloy 600 penetration remnant, the Alloy 52 external weld pad, the installed Alloy 690 half-nozzle, and the external partial Alloy 52 J-weld which attaches the half-nozzle to the weld pad. Figure 2 shows the overall finite element mesh used for the analyses. Figure 3 shows the mesh used for the repair area.

The membrane, membrane-plus-bending stresses, and stress ranges were calculated using the ANSYS stress distribution according to procedures based on ASME Section III Class 1 criteria. These were calculated at various locations in the penetration nozzle and the shell wall. Peak stresses were calculated using the fatigue stress reduction factor (FSRF) stipulated for partial penetration welds in NB-3200. The results indicate that all ASME Section III Class 1 design service level stress limits were met with ample margin. The cumulative usage factor (CUF) for the internal J-weld was conservatively calculated approximately as 0.34, and the CUF for the external J-weld was calculated about 0.05, well below the ASME Section III CUF limit of 1.0.

The NRC staff noted that the fatigue analysis of the internal J-weld did not account for the possible effect due to flow induced vibration of the internal penetration remnant. Framatome was requested to assess the significance of this omission. In Reference 1, STP provided a summary of the analysis and an evaluation of the effects of flow induced vibration. The evaluation showed that the fundamental frequency of the penetration remnant was significantly higher than the vortex shedding frequency and, therefore, the vibration induced by the flow would be minimal. The NRC staff concurs with this assessment.

The calculation also included a deformation analysis to determine the effect of thermal expansion on the gap between the remnant of the old nozzle and the new half-nozzle. The analysis indicated that the gap would not be affected in the axial direction. There is, however, a minimal relative movement in the transverse direction of about .005", which provides a small probability that it may interfere with the insertion of the thimble tube.

- <u>32-5028839, STP, Unit 1, BMI Nozzle to Guide Tube Connection Analysis and Qualification (Socket Weld)</u>

In Calculation 32-5028841, Framatome analyzed the socket connection between the thimble guide tube and the half-nozzle. The guide tube is nominally 1" diameter. The design of ASME Section III Class 1 piping 1" or smaller may be based on Class 2 rules for design of piping, which do not require an explicit fatigue analysis. However, based on considerations of conservatism, STP, Unit 1, elected to perform a Class 1 analysis of the guide tube to nozzle connection.

The evaluation of the socket connection is based on a similar ANSYS finite element analysis as the half-nozzle. Figure 4 shows the finite element mesh for this analysis. The socket is in the Alloy 690 half-nozzle and is welded to the 304 SS thimble guide tube with an Alloy 52 fillet weld. The stress and fatigue analyses of the weld connection were based on an envelope of the transients resulting from the thermal expansion and mechanical loads of the piping attached to the guide tube. The results show that the primary stresses meet the ASME Section III Class 1 design stress criteria by ample margins. The Class 1 fatigue analysis also indicated a low CUF. However, the calculation of the peak stresses and stress ranges did not include a FSRF for fillet welds of 4.0, as required by NB-3356. Although the inclusion of this factor is not expected to significantly affect the magnitude of the CUF at this location, i. e., the CUF is expected to remain well below the ASME Section III CUF limit, Framatome was requested to assess this omission. In References 1 and 2, STP, Unit 1, provided descriptions of this analysis which included the FSRF of 4.0 in the fatigue calculations. The CUF for the weld and guide tube were determined as 0.03 and 0.25, respectively, well below the ASME Section III Class 1 CUF limit of 1.0.

- C-3714-00-1, Rev. 1, BMI Nozzle Stress Analysis (Residual Stress Analysis)

This analysis was performed by Dominion Engineering, Inc. It is based on a finite element model of the interior J-weld, the shell wall, and the nozzle. Different models were devised for nozzles at different inclinations with respect to the shell wall normal direction. It is a highly complex analysis using the thermo-elastic-plastic capabilities of ANSYS, in which the thermal stresses resulting from the temper bead weld layering process were determined on a transient incremental basis, from the solidifying temperature to ambient temperature, considering the heat transfer to the shell wall, the variation of material properties with temperature, both elastic and elastic-plastic. The residual stress state is the stress state that exists once the region has cooled down to ambient temperature.

A description/summary of this analysis is presented in References 1 and 2. The analysis indicates that high residual circumferential stresses can exist in the weld and the nozzle wall, in the order of the average of the yield and ultimate stresses. However, in the vicinity of the welds, the magnitude of the stresses is closer to the yield stress. The residual stresses also vary around the weld circumference, being maximum at the downhill side of the inclined nozzle. The NRC staff sampled these calculations, and concluded that they appear reasonable and in accordance with industry and state-of-the-art stress analysis capabilities.

CONCLUSION

Based on this audit, the NRC staff concluded the following:

1) The thermal and mechanical transient conditions were generally consistent with the STP, Unit 1, current licensing basis.

2) The highly detailed FEM model of the reactor vessel wall in the vicinity of the nozzle, the remnant nozzle and the half-nozzle, the existing and new J-welds, was adequate to capture the regions with high stress intensity.

3) The primary and primary-plus-secondary stress intensities met the ASME Section III Class 1 design limits for all corresponding service levels.

4) The cumulative usage factors based on the peak stress intensity ranges met the ASME Section III Class 1 fatigue cumulative usage limit.

5) The calculations appear to support the implementation by STP, Unit 1, of the proposed half-nozzle repair method.

REFERENCES

1. Letter dated July 2, 2003, from S. E. Thomas, South Texas Project, Unit 1, to USNRC Document Control Desk, with Attachments.

2. Letter dated July 23, 2003, from S. E. Thomas, South Texas Project, Unit 1, to USNRC Document Control Desk, with Attachments.

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Date: August 8, 2003

REPAIR OF BOTTOM-MOUNTED INSTRUMENTATION PENETRATIONS

SUMMARY OF ASME CODE CALCULATIONS

JULY 2, 2003

Enclosure 3

REPAIR OF BOTTOM-MOUNTED INSTRUMENTATION PENETRATIONS

REVISED SUMMARY OF ASME CODE CALCULATIONS

JULY 23, 2003

Enclosure 4

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